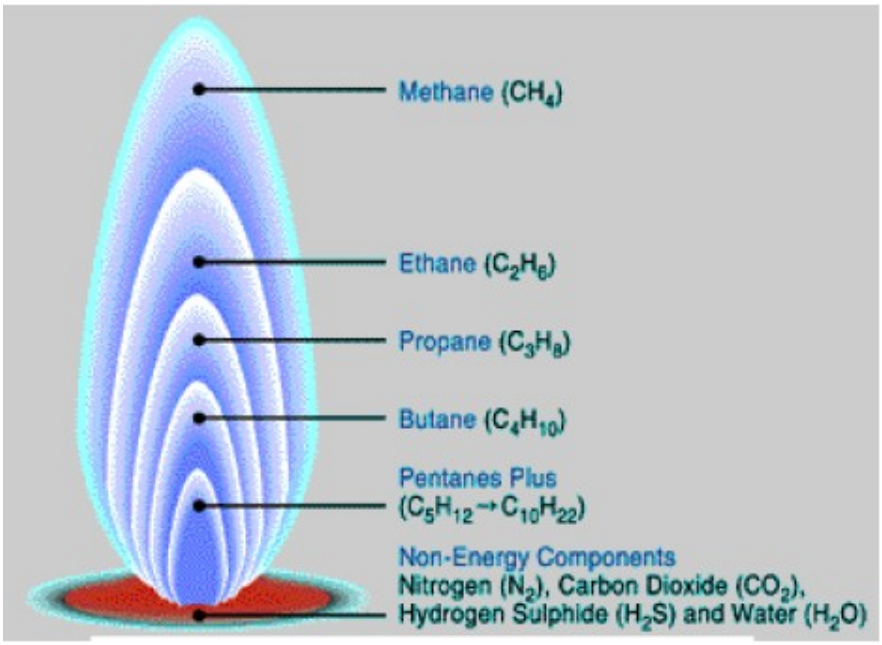
CHAPTER 5: Operation Part 7 Natural Gas Burners [1-2-3 of 5 points]

NATURAL GAS BURNERS



The information provided in this chapter on natural gas should be taken with caution and at the user's own risk, as it does not correspond to any particular regulations, but rather describes in a general way: information and personal experience, therefore its use is not the responsibility of the author, CWT.

The possibility of burning natural gas is already a reality (Natural gas has been in use in Paysandú since 1999 at ANCAP and in other industries since 2000). It has also been used in southern Uruguay since 2003. The benefit will not only be economic, since, for the same calorific value, it could be the cheaper gas (depending on the fuels being compared and the market situation), but also that gas combustion, if properly installed and adjusted, has fewer maintenance problems (but the system must be constantly monitored, especially the safety system and combustion results).

Since there will be no need to work with liquid fuels and soot will be a thing of the past (not quite, if there is a lack of air and a bad mixture, a very insulating soot can be produced without visible "smoke", which will be observed by an increase in the temperature of the chimney gases, as the transfer surfaces are insulated, the presence of CO and a darkening in the expelled gases will be noticeable, this soot can be expelled through the chimney and be noticed by the deposit on roofs and patios).

Supposedly, there will be less pollution due to the lower production of CO2 (carbon dioxide, one of the gases that cause the "greenhouse effect"), since natural gas contains more hydrogen (H) and less carbon (C). However, being a fossil fuel, it will still be polluting.

Nitrous oxides (nitrogen from the air and fuel, when oxidized by high temperatures, forms NOx, nitrogen oxides) will be produced in smaller quantities during combustion, and sulfur will supposedly be almost entirely eliminated in adequate supplies, thus reducing pollution from SO2 (sulfur dioxide). Both contribute to acid rain along with CO2, although SO2 is more corrosive, even highly irritating or toxic to living beings.

This will be beneficial if the gas burners are properly adjusted, without excessive air (generally no more than 15% excess on the high side and 30% excess on the low side) or insufficient air, or other combustion problems related to the burner or its adaptation to the boiler (which could cause unburned gases).

BUT BE CAREFUL! There will be a greater chance of accidents involving the fuel if things aren't done correctly.

For example: a gas leak into the boiler room environment could ignite violently simply by turning on the light (boiler rooms must be very well ventilated), or a burner purge could cause a combustion explosion (or other malfunctions).

The presence of CO due to incomplete combustion (since combustion cannot be adjusted by eye; there could be insufficient air, inadequate air-gas mixture, or a cold flame, resulting in incomplete combustion) can be a problem, as CO is a colorless and odorless gas that is toxic when accumulated or present in excess in an environment.

We only realize it through the symptoms: headaches, vomiting, dizziness, etc., which generally disappear upon leaving the contaminated environment (a boiler room or any other contaminated space). There are electronic detectors with alarms for detecting carbon monoxide. However, carbon monoxide (CO), at a certain concentration and exposure time, causes death (a very common occurrence in cars in cold countries, where closed windows and unventilated vehicles, often left in traffic jams, leave the engine running for heating. If the exhaust pipes leak combustion gas, rich in CO, when the engine is idling, and this enters the car, it poisons the occupants).

Here we must divide the problem into 5 points:

1- the problem of receiving the gas properly with all the necessary safety elements,
2- the burner must meet all the requirements for burning natural gas,
3- the boiler room must be adequate,
4- the burner must be adjusted using instruments,
5- the personnel must be carefully instructed and trained.

1- The problem of receiving the gas properly with all the safety elements:

The natural gas pipeline supplier (we will refer mainly to this), will supply a gas that is as “standard” as possible within the agreed conditions (that is, natural gas varies from supply to supply), since it is a composition of different gases in which carbon -C- and hydrogen -H- combine in different ways, forming gases whose carbon to hydrogen ratio varies and with it varies their capacity to react with oxygen, the calories they can give, the combustion rate, etc.

The predominant gaseous form will be methane, whose formula is CH4. It contains a high proportion of hydrogen relative to carbon (it is also called "swamp gas" because it is produced naturally by the decomposition of organic matter).

Furthermore, it is a colorless, odorless gas, slightly soluble in water, and highly flammable. The molecular weight of methane is 16, meaning it has a much lower density than air, which has an average molecular weight of approximately 27.

Supposedly free methane tends to rise in the atmosphere, or in a room, it will rise to the upper parts.

Natural gas cannot be liquefied at low pressures (like bottled gas, which is made up of heavier gases) at ambient temperatures (its temperature must be lowered to very low values so that the pressures at which it liquefies are not high in the containers).

For this reason, it is necessary to transport it through pipelines at high pressures (to increase its weight per unit volume). Transport can be carried out at pressures exceeding 70 kg/cm² and speeds of 40 km/h, so that the pipelines do not need to be very large, and the gas is pumped through them

using large gas compressors.

Once it reaches the site of use, the pressure will be lowered to an average value acceptable for the supply of the local network, being lowered even further at the final place of use, where the pressure will generally be relatively low (centimeters of water column: cm.w.c. or meters: m.w.c. or millibars: mb which is equivalent to 10.2 mm.w.c., in practice 1 cm.w.c. or 10 mm.w.c.).

As for natural gas, after its extraction from the wells, it must be prepared for use, in which condensable elements (hydrocarbons that condense under pressure), water and entrained solids are removed, the sulfur content is reduced, etc., depending on its composition.

For example, let's look at the composition of a natural gas:
Typical composition of a **natural gas** (% by volume):
Methane....CH4..... 88.1%
Ethane.....C2H6..... 4.90%
Propane...C3H8..... 2.30%
Butane.....C4H10..... 0.70%
Pentane....C6H12..... 0.10%
N2+O2.....1.40%
CO2.....2.60%
Supply Heat Value (MJ/m3) 39.6 Mj/m3
Relative Density (air=1)..... 0.643
Woube Index..... 49.4

Now let's look at the composition of natural gas in Paysandú Uruguay (November 1999)
Molecular Weight %
Methane CH4 16.041 90.984%
Ethane C2H6 30.067 4.083%
Propane C3H8 44 1.196%
N-Butane C4H10 N 58.118 0.330%
Isobutane C4H10 I 58.118 0.210%
Isopentane C5H12 N 72.144 0.091%
N-Pentane C5H12 I 72.144 0.080%
N-Hexane C6H14 86.169 0.116%
Carbon Dioxide CO2 44.01 1.967%
Nitrogen N2 28,016 0.935%
Relative density (air=1).....0.624
Density (weight per volume)... 0.76 Kg/m3
P.C.S. 9,402 Kcal/m3 or 12,292 Kcal/Kg.
P.C.I. 8,494 Kcal/m3 or 11,105 Kcal/Kg.
Woobe Index.....49.8

To detect leaks by smell, an odorant (generally mercaptans, sulfur-based compounds with a typically very strong and unpleasant odor) is injected at the distribution terminals.

This will make any leaks into the environment detectable by smell. (This is required by law to prevent accidents. The odorant is typically injected at approximately 3 mg/m³ at the point of consumption and no less than 5 mg/m³ at the injection point, depending on local regulations. Its odor must be noticeable in the presence of a leak.)

In Uruguay, the Argentine standard NAG 100, which allows for the detection of natural gas concentrations of approximately 0.2% in the air, is currently in effect (2004). Control of this standard is the responsibility of URSEA (Regulatory Unit for Energy and Water Services).

Electronic gas sensors are also available and must be installed in areas where a certain volume of gas is handled and where, for safety reasons, gas accumulation must be prevented to avoid the risk of explosion.

These electronic devices generally work in various ways, but they don't detect odor; rather, they detect the physicochemical properties of the gas. The oldest of these are called "explosimeters."

These devices operate based on the combustion of any gas present in the environment. This combustion takes place inside a "cell" containing a catalyst. The device detects the heat energy released when a given proportion of the gas combusts with oxygen from the air. The amount of heat indicates the proportion of gas present. More modern devices analyze other properties of the gas.

Gases "explode" within a certain proportion with air; a small electrical spark (like the spark from a light or flashlight switch), a mechanical spark (the impact of one iron tool on another iron or stone), a "static" spark (caused by the friction of two elements), or heat (since if it comes into contact with temperatures above 600°C 1112°F, it combusts) is enough.

In the United States, in 1999, the power plant at the largest auto assembly plant exploded, killing, injuring, and burning numerous workers.

This explosion occurred in a boiler that was shut down for inspection: a small leak of natural gas filled the furnace of a large boiler (in a room with several high-pressure boilers in operation). This gas, mixed with air inside the

furnace, for some reason ignited in an explosive combustion (spark, small light source, etc.). This disaster, at the end of the 20th century (a time of high technology), clearly demonstrates the need for caution when using natural gas.

Another case occurred in Uruguay in the late 1980s. A welder entered a large boiler (a water-tube boiler of a sectional boiler) while using a gas cylinder (supergas) for cutting with a blowtorch.

Even with the blowtorch off, a small leak began to fill the combustion chamber with gas until the mixture with air created an explosive mixture. When he used an angle grinder to grind the metal, a spark ignited the mixture, killing him.

Another case occurred in Uruguay at the end of 2003. Due to a lack of training of personnel by the company supplying a "dual" burner for fuel oil and natural gas, a "combustion chamber explosion" occurred after the first operation using heavy fuel oil. This was caused by a natural gas outage of only a few hours, when they attempted to restart the burner with natural gas.

The gas feed nozzles were clogged with fuel residue, slag, and concentrated fuel, which prevented the gas "ring" from igniting initially, causing a concentration of gas in the combustion chamber (perhaps increased by the release of gas from the fuel oil residue). When this gas ignited at the end of the main flame establishment period or earlier (either by the pilot light or by a fire in the deposited soot that was reignited during the purging process), it caused a violent explosion, seriously injuring those attempting to start the boiler with gas.

Unfortunately, there are many examples of this. With gas, we must be very careful when working in an area where it can accumulate (avoiding any leaks, keeping vents in good condition, sweeping with air or preferably working in an air current, avoiding the accumulation of gas in enclosed spaces).

A common problem is that boilers in buildings are located in lower areas (such as basements), so if fuel accumulates due to leaks (or, being lighter than air, rises and enters upper spaces), it can cause an explosion with the "demolition" of the building.

Boilers in general, and especially gas boilers, should be located in well-ventilated areas, with enclosures made of lightweight structures, so that in the event of an explosion, the building structure doesn't become like a grenade.

In other words, the explosion should be easily contained. Unfortunately, Uruguay has many examples of installations that are ideal for causing significant damage.

The leaner the mixtures, the more dangerous they are (the flame speed is very high) and the richer the gas, the slower they are (the flame speed is lower), meaning that there is a minimum value of gas to mix with air to "explode" and a maximum value above which, if we are with the mixture above a certain proportion, ignition no longer occurs.

Combustion Limits for Air-Gas Mixtures

Gas	Low%	High%
Hydrogen	4.0%	75.0%
Acetylene	2.5%	80.0%
Methane	5.3%	14.0%
Natural Gas	5.0%	14.0%
Town Gas	5.0%	37.0%
Propane	2.2%	9.5%
TLP	8.0%	36.0%

(TLP: tempered liquid petroleum gas)

As seen in the table above, methane and natural gas have almost the same limits, since natural gas is mostly composed of methane.
This table indicates that low percentages of loss in an environment can be very dangerous.

The other factor that determines a gas's combustion advantages and risks is its ignition temperature.

In the case of methane and natural gas, depending on the percentage of mixture with air, the approximate ignition temperature is:

% of GAS IN AIR	4%	6%	8%	10%	12%	14%
For Methane, °C	635	6375	642	648	659	670
°F	1175	1178	1187	1198	1218	1238
For Natural Gas, °C	632	612	611	612	613	617
°F	1169	1133	1131	1133	1135	1142

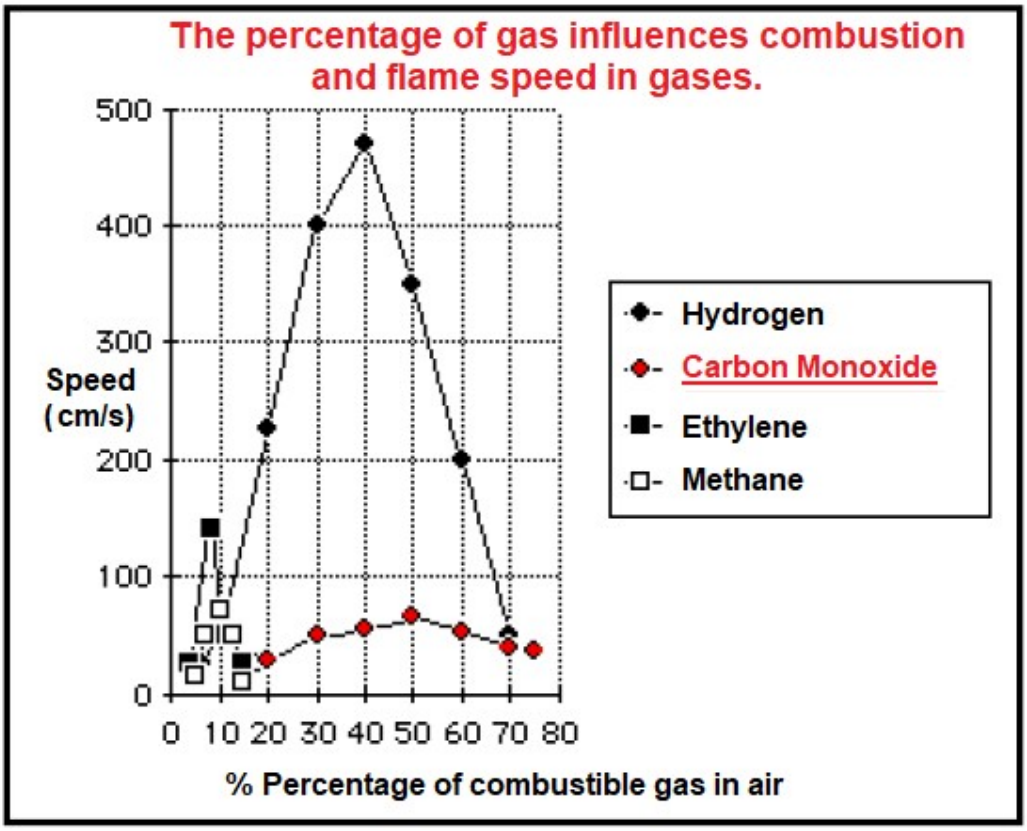
A temperature of +600°C (1112°F) can be produced by a static spark, a light switch being turned on, a broken incandescent lamp, a simple flashlight not

protected against explosion, or a simple metallic impact (iron, steel, cast iron, but there are special tools made of copper or other metals that do not produce sparks when struck).

Flame speed is very important, both for combustion in a burner and in an explosive mixture. Hydrogen is the element with the highest combustion speed. Since natural gas contains methane as its main component, which is very rich in hydrogen, it might seem that its combustion speed would be very high. However, this is not entirely true due to the presence of other elements.

The flame speed of typical natural gas in a Bunsen burner (an open burner) can be measured at approximately 300 mm per second (hydrogen is about 2830 mm per second). The maximum flame speed of typical natural gas occurs at 100% of the theoretical air required (or minimum air, approximately 9.8 m³ of air per m³ of natural gas, close to a "lean" gas mixture, i.e., 5% by weight).

In a tube, such as in the hearth of a fire-tube boiler, the velocities vary, see the graph below, in a 1" diameter tube (inside the fire-tubes, from 2" to 3", the flame is extinguished by cooling, so combustion must be completed before the gases reach and penetrate the fire-tubes).



The combustion rate is very important for flame behavior. It depends on many factors (the mixture, the percentage of air, the temperature, the composition, the shape of the combustion chamber, the pressure, etc.). The graph above shows flame or combustion rates in a 1" diameter pipe, which may vary as discussed.

As can be seen, hydrogen in a 40% air ratio has the highest combustion rate. The main component of natural gas is methane, so the combustion rate is similar to that of methane.

It is generally thought that natural gas (or wood gas as in a gas generator) will have a very high combustion rate, this is not the case, since the composition of the flame varies during combustion time, and the flame temperature also varies as it moves away from the burner (it increases and then decreases)

In liquid fuels like fuel oil (rich in carbon), the flames are very bright, accelerating combustion due to the catalytic effect of the incandescent carbon particles within the combustion chamber (a bright flame; the incandescent carbon particles accelerate combustion through radiation, an effect sometimes attempted with fuel additives).

Natural gas flames, on the other hand, are low in carbon (low-luminosity flames; there are no incandescent particles to accelerate combustion), resulting in a long, diffuse flame with an indistinct end.

Do not confuse the amount of heat with the flame's capacity to transmit heat by radiation, since carbon produces less heat per kilogram than hydrogen.

This slow combustion rate in the gases can be a source of noise or vibration if the boiler's combustion chamber is insufficient in diameter.

The flame's combustion speed is determined by the velocity of the mass of gas and air being burned, especially in the cold zone or at the beginning of the flame. This can cause unstable pressures in the combustion chamber tube, resulting in noise or vibration (similar to a plumber's gas torch).

Therefore, it is necessary to create the best possible mixing of air and gaseous fuel (a mixture sometimes called turbulence) to increase the combustion rate.

Flames with a lower H/C (hydrogen/carbon) ratio (less hydrogen) produce a brighter, shorter flame with high radiant transmission, improving the efficiency percentage in the same boiler (although they are more prone to producing soot).

This is illustrated in the following table. Furthermore, the presence of hydrogen (H) influences the process, since more hydrogen increases the amount of water formed. Because efficiency in this case is represented by the Higher Heating Value (HHV), it is more affected than the Lower Heating Value (LHV).

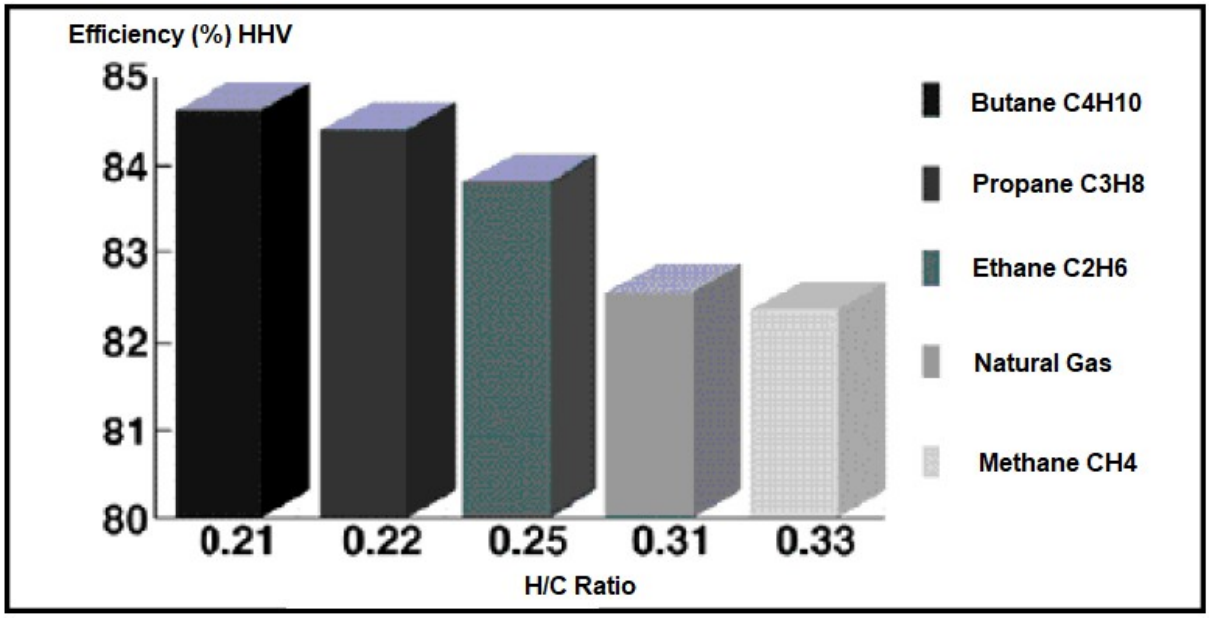
The HHV efficiency better assesses fuel behavior—specifically, the presence or formation of water—while the LHV efficiency... It better evaluates the boiler's performance.

		densidad		
		Kg/m3	P.C.S. Kcal/k	P.C.I. Kcal/kg
METANO	CH4	0.6796K/m3	13,266.46	11,955.87
ETANO	C2H6	1.2860K/m3	12,400.32	11,351.41
PROPANO	C3H8	1.9156K/m3	12,034.20	11,080.29
NBUTANO	C4H10 N	2.5339K/m3	11,838.09	10,933.62
ISOBUTANO	C4H10 I	2.5339K/m3	11,809.75	10,905.28
PENTANO ISO	C5H12 N	3.0496K/m3	11,717.53	10,843.06
PENTANO N	C5H12 I	3.0496K/m3	11,695.86	10,821.39
N HEXANO	C6H14	3.6423K/m3	11,633.64	10,779.72
ANHI.CARBON	CO2	1.8740K/m3	0.00	0.00
NITROGENO	N2	1.1915K/m3	0.00	0.00

The lower the density of a gas (the more volume it occupies per kilogram), the greater its calorific value per kilogram and the lower its calorific value per volume.

The presence of hydrogen (H), a very light element (atomic weight 1), when combined with oxygen (forming H_2O, or water), produces the greatest amount of heat per kilogram, but it occupies a large volume in its gaseous state (it is a gas that was used to inflate balloons and zeppelins, but is very dangerous due to its explosiveness; it is used in high-temperature torches, such as those used for underwater cutting, etc.).

Observe the table below which compares the different gases in their H/C ratio with respect to Combustion and Transfer Efficiency referred to the HHV (Higher Heating Value), not only due to the amount of combustion water they form, but also because the luminosity of the flame that contains more carbon transmits radiant heat better in the home.



It is clear that the **average user will receive the gas at a low pressure and with the "presence by odor" indicator already included**, but in any case, **to use said gas there will be a final reduction station, before the burner** (it will depend on the type of user).

This **final pressure reduction station** must comply with established standards, which generally require that the reduction be done in such a way as to **provide a constant pressure output**, since any variation in pressure could affect its final use (such as combustion regulation in the burner), as well as **overpressure protection** or in case of **supply interruption**.

It is clear that if there are **overpressure relief or vent valves between intermediate stages, these "leaks" must be discharged in areas free from the risk of accumulation inside the building** (or in some cases onto a flare with a pilot light so that the discharges burn off without affecting the environment; this depends on the importance of the installation).

Similarly, **the burners must have protection that, in the event of a drop in gas pressure, shuts them off and prevents them from reigniting until the supply pressure is properly restored** (gas pressure switch).

The gas must be free of foreign matter and have a very low water content. Furthermore, pressure reducing or controlling valves must be protected with filters and water traps.

Also, **when valves have diaphragms or packings that could leak gas into the atmosphere, these leaks are generally collected in a safe venting system that discharges into an open area**, away from where it could accidentally accumulate, or into a free nozzle where it can be safely burned (therefore, a pilot light must be present to initiate combustion in the event of leaks).

The calorific values of gases are expressed in relation to volumes. When this is the case, we must consider the pressure and temperature to which they refer, since the weight per cubic meter of the components will vary depending on the pressure and temperature.
Expressions of gas volumes are only meaningful when the pressure and temperature at which the volume is expressed are specified.

In the case of natural gas, volumes are sometimes expressed as Nm^3 (normal cubic meter), which is 1 m^3 of gas at 760 mm Hg absolute pressure (760 millimeters of mercury) and a temperature of 0°C (32°F).

A practical unit is the nm^3 (standard technical cubic meter), which considers the gas to be at an absolute pressure of 760 mm Hg. of Hg but at a temperature of 19.2°C (66.5°F) or 1 kg/cm^2 absolute pressure and 10°C (50°F) temperature,

this simplifies some calculations when working with the molar value—the volume occupied in m^3 by the molecular weight in kg of the gas—since the decimals are removed from the Nm^3 equivalence to the molar value. In the case of Nm^3, the value of 1 mol is taken as 22.414 m^3, and in the case of nm^3, it is taken as 24 m^3, this being a whole number that facilitates the calculations.

But a commonly used measure refers to standard conditions, such as the gas being at 15°C (59°F in the U.S.A., actually 60°F, which corresponds to 15.5°C) and 1 standard atmosphere.

(1 standard atm = 760 mm of mercury = 1.033 kg/cm^2 = 1013.25 mb or millibar = 101.325 kPa or kilopascal or 14.7 lb/in^2 or pounds per square inch).

In Uruguay, Decree 78/999 of March 22, 1999, established that the cubic meter (m³) of natural gas must be measured at a temperature of 15°C and a pressure of 101.325 kilopascals (similar to the Argentine standard).

This condition must be taken into account, since the cubic meters (m³) measured for billing purposes for natural gas consumption are based on these temperature and pressure conditions.

However, gas meters must be corrected, as they will be measuring the gas at the pressure of the pressure regulator and ambient temperature (temperature, whose variation is disregarded in low consumption; in high consumption, the meters may have an electronic pressure and temperature corrector that gives the corrected m³ of gas to standard m³).

To this must be added the factor of the ratio of the calorific values, actual GHV and agreed GHV, which is also influenced by its calorific value (which can vary). **This correction factor or "conversion factor" will be multiplied by the m³ difference indicated by the meter during the period.**

This "conversion factor" must also consider the calorific value of the gas (that is, a calorific value per standard cubic meter of gas is agreed upon, which, for example, for the natural gas supplied in Paysandú, Uruguay, is 9,300 kcal/m³ HGS in the year 2000).

We must pay attention to the "conversion factor," since if the pressure regulator changes its setting, the conversion factor must also change (in liquid fuels, consumption can be controlled by volumetric or weight measurements, which is not the case with gas; different methods must be applied, or indirect monitoring of gas usage must be maintained).

Let's take an example: the supplied gas has a gauge reading of 800 mbar (0.8 bar) and the gas's GCV (Gross Value of Gas) is 9,336 kcal/m³. The agreed-upon GCV is 9,300 kcal/m³. The meter's conversion factor will be (calculated using kg/cm²):

Conversion factor = [(1.0333 + 1.020 x 0.800) / 1.0333] x (9,336 / 9,300) = 1.796

Or, calculating in bar: [(1.013 + 0.8) / 1.013] x (9,336 / 9,300) = 1.796

The conversion factor is a ratio and is not given in any unit.

The cubic meters (m^3) read on the gas meter must be multiplied by this factor to determine the cubic meters of gas to be paid for:

(m^3 metered) x 1.796 = m^3 to be paid for (on the bill)

The first part ((1.0333 + 1.020 x 0.800) / 1.0333) corrects the volume variation per m^3 at the meter pressure to the standard pressure. The second part (9.336 / 9.300) corrects the calories supplied to the agreed-upon calories per m^3 of standard pressure.
The product of the two gives the conversion factor.

It does not correct for temperature variations (for this, meters with automatic conversion are used).

This highlights the importance of the meter operating at the specified pressure (by observing the pressure gauge and maintaining its periodic calibration), because **if the pressure on the meter drops, it will measure more m^3 than expected (this also occurs with temperature**; if it rises above normal, it will measure more m^3 than the actual volume.

In this case, it will only be useful if the compensation caused by the average between low and high temperatures is close to the standard, or if it has an automatic electronic corrector to adjust the measured m^3).

As we said, the higher calorific value (HCV) of a gas can be stated for example: 9,245 Kcal/m3 (standard cubic meter: 15ºC and 760 mm. Hg absolute), but it can also be expressed in MJ (mega-Joules, where 1MJ= 238.9 Kcal.).

Or, it could be said that the higher heating value (HHV) of this same gas is 12,709 kcal/kg (not dependent on pressure, but rather on the temperature, which is assumed to be at a certain value, generally 0°C 32°F).

We can also define that for this gas (this particular one), a minimum volume of air is needed for its complete combustion, saying, for example, that 1 m^3 of this gas requires 9.8 m^3 of air for its complete combustion.

However, since gases have many variations in composition, a calculation has been defined to determine if one gas can substitute for another in the same burner and at the same gas pressure.

This calculation uses an index called the Woobe Index, defined as the ratio between the Higher Heating Value (HHV) and the square root of the

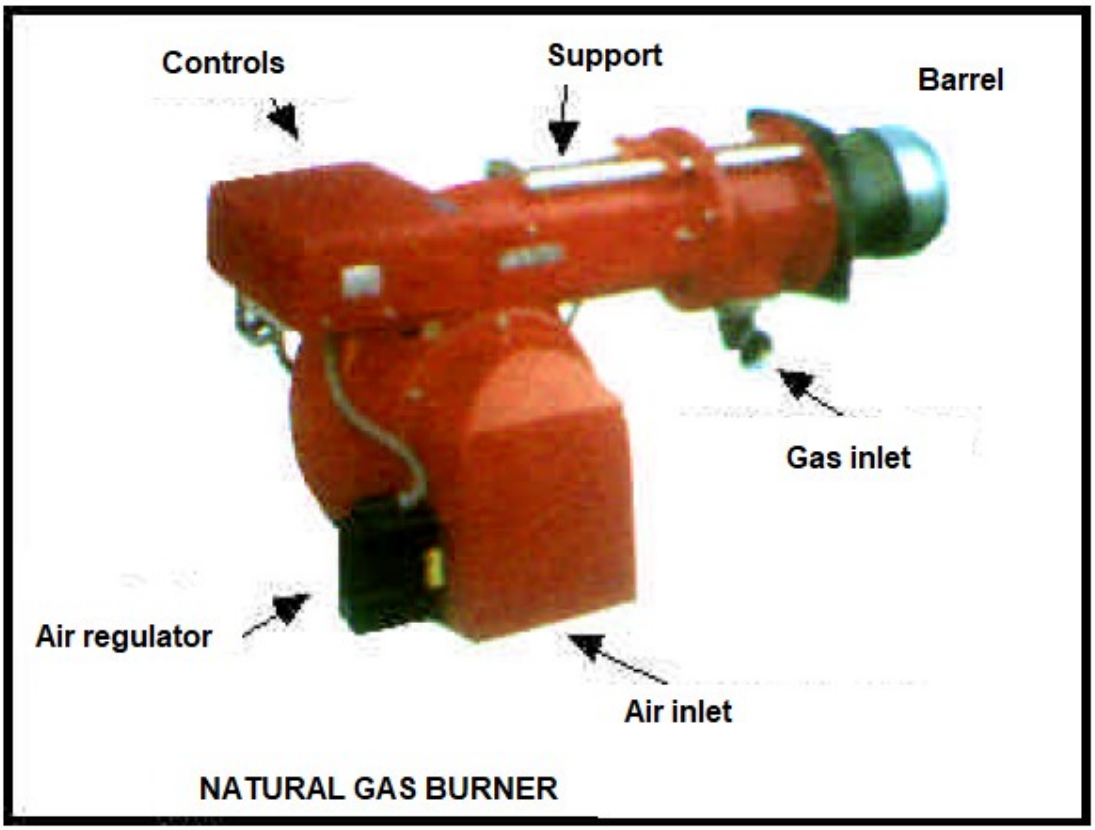
relative density (using the HHV in MJ/m³ and the relative density relative to air, where air = 1).

For example, if the gas has a HHV of 40.1 MJ/m³ and a relative density of 0.64, the Woobe Index will be 50.1.

At similar or close Woobe indices, these fuels can be interchanged in the same burner without needing to change the gas injection nozzles; otherwise, changes will have to be made to the burner each time different gases are used.

For example: General specification for piped natural gas:

Higher Heating Value..... 36.51 to 41.0 MJ/m³
Wobbe Index ..... 46.02 to 50.86
Water..... 112 kg/m³
Hydrocarbon dew point.....max.. 2.2°C at 7 MPa (relative)
Oxygen.....max. 0.2% vol.
Total Sulfur.....max... 45.74 mg/m³
Hydrogen Sulfide.....max... 6.0 mg/m³
Sulfur Mercaptan.....max... 4.57 mg/m³



2- The burner must meet all the necessary requirements for burning natural gas:

Handling natural gas “seems easy,” but if we want to avoid accidents, we must ensure **that the burner complies with all safety standards** (in Uruguay, Argentine standards have been adopted, but also European ones, since burners from all over the world are used). This includes ensuring the programmer is suitable for gas (generally, there is more consideration given to the purging process—4 air changes per minute in the combustion chamber volume—than in a liquid fuel burner).

If reignition occurs, the purging process must be repeated each time (in large boilers, there will be no re-ignition, only post-purge, and the boiler operator must perform the “reset” or “reset” of the burner, which will be “locked out” due to ignition failure, so that the boiler operator can investigate the fault).

In "small" boilers there may only be a "spark" for direct ignition of the main flame, but in larger boilers there must be a gas pilot flame that is ignited by the "spark," and in some cases, the pilot flame may always be lit to prevent the presence of unburned gas.

But in automatic burners, the pilot flame will be interruptible, meaning it will operate for a few seconds with the electric igniter to ignite the pilot flame, then for a few seconds to establish the pilot flame on its own so that the flame control photocell (special for gas) "sees" it.

The pilot will remain lit for a few seconds to ignite the main flame (about 3 to 5 seconds more for the main flame to establish itself, depending on the burner's capacity), which must shut off in 1 second if the pilot goes out and/or the main flame does not establish itself.

In other cases, there may be an intermittent pilot light, meaning it remains lit as long as the main flame is lit.
Each case will depend on the importance of the burner and the type of boiler (according to the regulations and/or the boiler manufacturer).

The "power" or flow rate of the main flame at ignition must be a fraction of the maximum flow rate (or maximum burner power). As the boiler's capacity increases, this fraction decreases (reaching 20% in the largest boilers).

Only in small-capacity boilers (less than 100,000 kcal/h) can the main flame be ignited at full flow rate. **However, all the "safety" enabling valves in the valve train that supply gas to the burner must open slowly (to prevent an ignition explosion) and close rapidly (in less than 1 second in larger boilers).**

Flame control can be achieved using an ionization rod to monitor the flame, and/or a combustion (flame) detector that uses ultraviolet light instead of visible light or infrared, or both.

It is very important to comply with the regulations established by the authorities in each region or country.

The ionization rod is based on the principle that gas combustion ionizes gas particles, creating particles with positive and negative charges (which allows us to pass a certain electrical current between two elements subjected to a certain voltage; dry air does not conduct electricity).

Using this property, the rod or electrode is at a voltage relative to "ground," that is, the metallic "mass" of the burner or another electrode.

If combustion occurs, current flows, activating a circuit to detect the flame. If there is no combustion, the current is not established, and the circuit does not detect it.

The electromagnetic spectrum that makes up light has frequencies (like radio waves or television) at which some are visible—visible light, which is made up of the primary colors.

But at lower frequencies, we enter the infrared spectrum (those we detect by the heat they transmit). At the other end of the light spectrum are ultraviolet light waves (which are almost invisible).

The combustion of natural gas produces more ultraviolet waves (almost invisible or invisible).

In common burners, the common photoelectric cells or silicon or germanium photo-iodes are generally not suitable for gas, because gas transmits few visible or infrared waves. **Therefore, if there is a conversion of a liquid fuel burner to burn gas, this is one of the points to consider, since it may be a cell exclusively for liquid fuel, which generally detect more visible or infrared waves.**

UV (ultraviolet) sensors have generally been the most commonly used for gas detection (photodiodes with filters or ionization rods can also be used).

Ionization rods can be used in conjunction with UV sensors. **The response time for detecting a flame failure is a maximum of 3-5 seconds** (though some modern photocells are less than 1 second) when the pilot light attempts to ignite, and then the main flame fails.

The pilot light is ignited by the igniter, which is set beforehand in about 3 seconds (it is not detected by the flame detector). **The gas pilot should ignite within 3 to 5 seconds, and the igniter should be turned off to see if the pilot flame stabilizes (this should be observed by the flame detector).**

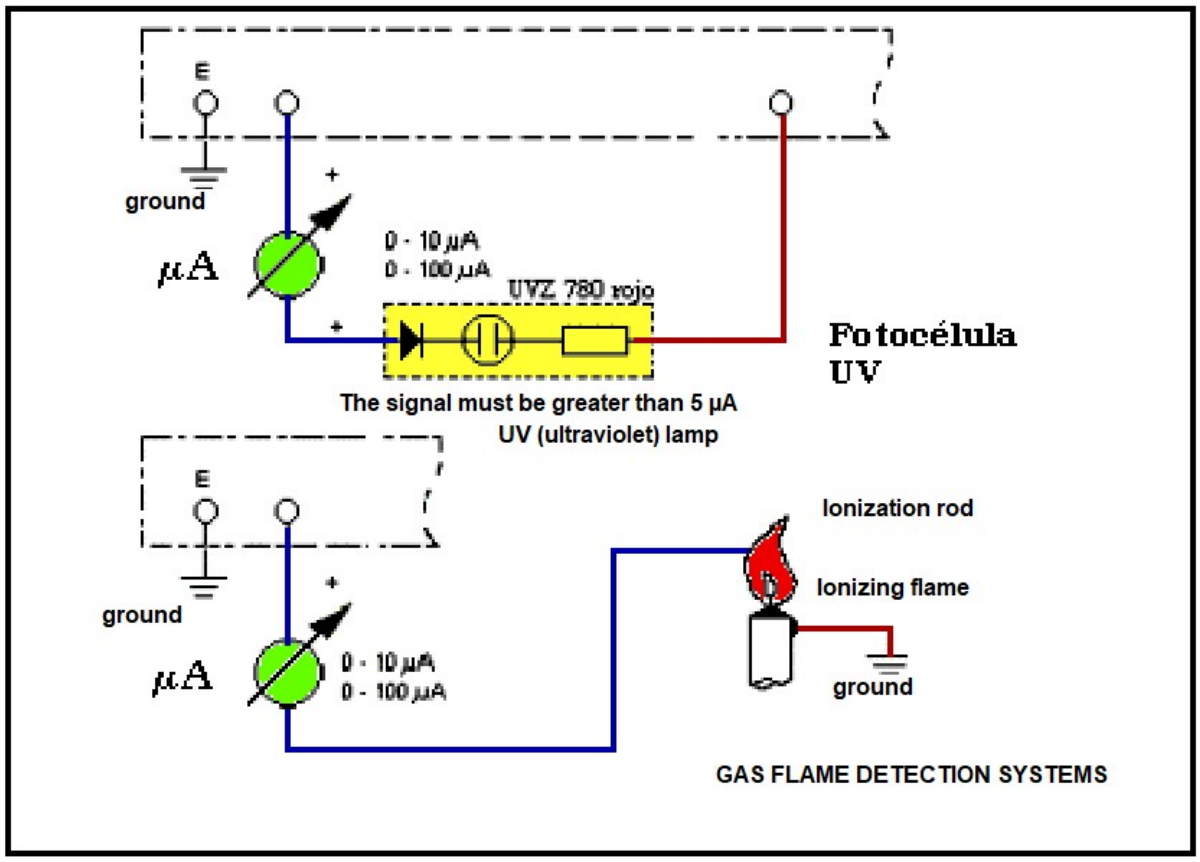
If the gas pilot does not stabilize, the gas supply to the burner will be cut off in less than 1 second, and the burner will be locked out with the fault light and alarm activated until the operator inspects and restarts the burner (resetting it).

In other words, the response of the flame detector is generally less than 1 second and the quick-closing valves are practically instantaneous (less than 1 second), this depends on the "power" of the boiler (capacity, see table below).

The main flame ignites within 3 to 5 seconds, depending on the burner type and power, in the minimum flame setting (20% of maximum capacity in larger boilers), if the main flame does not ignite within this time, the burner "locks out" due to lack of flame (since it only has 3 to 5 seconds to ignite).

This triggers a post-sweep and indicates the lock position by illuminating the "lock" light and sounding an alarm (with the fault indicated on a display or the time it occurred on a rotary dial).

Some photocells, which operate in the infrared range, run the risk of detecting the heat from refractory materials, which can cause them to fail to shut off due to lack of flame. For this reason, photocells must be selected by a trained technician and in accordance with the standards.



UV-type photocells, with the appropriate circuitry, can work by detecting, in the case of some flames, a "frequency or alternation" produced by combustion, so that there is no way to mistake the presence of a flame for the heat produced by refractories that do not produce said "frequency".

In turn, some of these circuits have permanent intrinsic checks to determine if the photocell tends to "wear out" or another problem that could cause a false reading of the presence or absence of a flame.

UV flame sensors and "ionization rods" work, in a way, on the same principle: the ionization of a gas between two plates or conductive elements (the ionized gas means that its molecules are positively and negatively charged, allowing a small electric current to flow when subjected to a voltage between these "plates" or conductive parts).

UV photocells are actually a "glass tube" like a light bulb (they're like the ones we used in old vacuum tube radios and called "diodes" because they have two electrodes), sealed with plates, one called the "cathode" and the other the "anode."

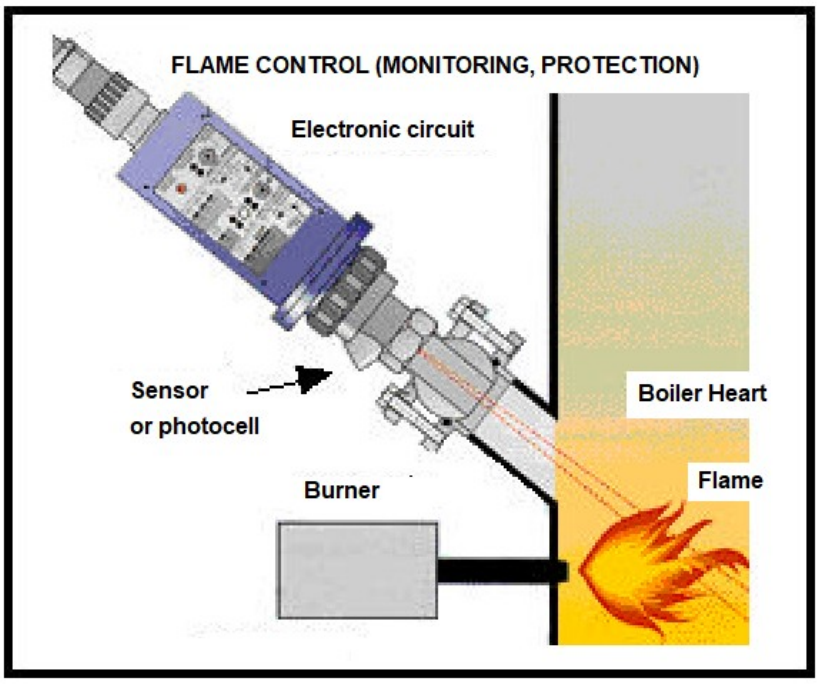
Inside the tube, instead of air or a vacuum, there's a gas that ionizes when illuminated by ultraviolet light. This allows it to conduct a small electrical current, which is used to operate a relay that controls the burner's electrical circuit.

The ionization rods are actually similar to the electrodes of the burner's spark system, since a single electrode is given voltage with respect to the "ground" formed by the metal burner, and air by itself does not ionize, but when there is a flame (combustion gas) it ionizes and allows the passage of a small electrical current that is used to operate a relay that controls the burner circuit.

According to the standards, two flame control systems can be installed in parallel (American standards allow this so that one can be removed for maintenance without having to shut down the burner).

However, Argentine standards only allow two flame control systems, meaning that each flame control operates independently of the other. Therefore, if either one fails, the burner will shut down.

When the burner output is of a certain importance (more than 5,000,000 Kcal/h) the flame control sensors must be "self-testing" (with "intrinsic safety", i.e., able to test themselves and block the burner if there is a failure in the system) especially if the boiler is running continuously.



A burner of a certain power output must have a combustion **air supply pressure sensor** to ensure that combustion air is present when the burner ignites or operates (because if gas enters and there is no "purge" or combustion air, and the igniter ignites, a combustion explosion is almost certain).

The "electrical interlock" of the burner fan is not sufficient (as the fan itself could break the connection between the motor and the fan's impeller).

When there are multiple burners on the same boiler, each burner must have its own independent pressure and flame sensor.

To all these elements must be added the "train" or set of safety valves (with their "leakage" test elements, i.e., gas loss from the valves) and control, with their pressure switches, "position" sensors, regulating valves, etc., as we will describe later.

3- The boiler room must be adequate:

It is clear that the boiler room must have good ventilation, meaning there must be constant air exchange to prevent gas from accumulating in the room, as this can lead to violent combustion (lean mixtures produce more violent explosions than rich mixtures).

Remember that natural gas is a mixture of gases, some light like methane (CH4, almost 95%), others heavier like ethane (C2H6) and propane (C3H8).

This means that some of the lost gas will rise (most of it) and some will sink.

In a gas conversión (fuel to natural gas burners), especially in buildings, heating boilers often suffer from a significant lack of ventilation.

This ventilation must allow for the extraction of stale air or suspected gas leaks into the atmosphere, not into other areas where they could accumulate.

Remember that when installing exhaust fans, we must also ensure there are adequate air intakes; otherwise, proper air exchange will not be possible.

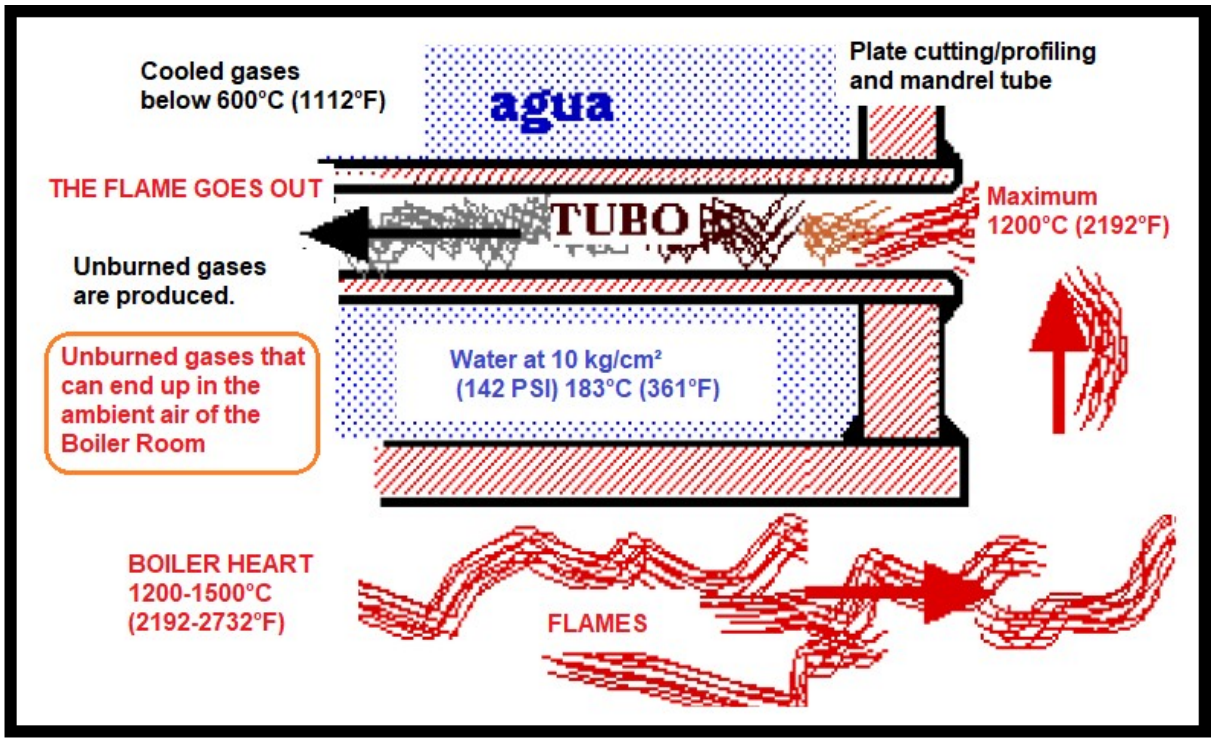
The combustion chambers of older boilers were generally under negative pressure, meaning that the chimney created a draft or suction in the boiler's combustion chamber when the boiler was running (a few millimeters of water column, depending on the chimney's height and diameter, flue gas temperature, and boiler type).

Modern natural gas boilers tend to have a pressurized combustion chamber when they are running (the gases are forced through the tubes and their retarders, if used), and negative pressure will only be present in the combustion chamber when the boiler's combustion chamber is off (and the burner's air intake is closed).

This means that in pressurized combustion chamber boilers, combustion gas leaks can enter the room. In other words, in natural gas boilers where the burners pressurize the combustion chamber, gas can escape into the room through poorly sealed combustion chamber lids or smoke boxes.

Boilers with a slightly negative pressure in the combustion chamber are less likely to experience combustion gas leaks into the room.

It's important to remember that once combustion extends beyond the flue pipes, the flame goes out and unburned gases are generated.



These unburned gases can be released into the environment as unburned gases, especially in the flue or chimney connection.

This can also happen when chimneys are clogged by corrosion, old soot, or debris, or when they are poorly designed or constructed. (Sometimes an internal chimney fire causes the flue to contract, which isn't visible from the outside, creating a partial obstruction that prevents proper chimney draft.)

These gases, produced by incomplete combustion, can not only be explosive but are also highly toxic, especially due to the presence of carbon monoxide (CO).

Remember that carbon monoxide (CO) is a gas whose effect on the human body is cumulative with prolonged exposure to contaminated air. This means that prolonged exposure increases the risk of poisoning, even with low levels of carbon monoxide (CO).

Carbon monoxide (CO) is a colorless and odorless gas.

Generally, before it can have a fatal effect, it causes headaches and nausea, and before that, there are some other barely noticeable symptoms. For example:

According to the Bureau of Standards (paper 212), 8% CO exposure can be fatal for 1.5 hours, but 4% CO exposure can also be fatal for slightly over 4 hours.

However, if a person remains in a contaminated environment for extended periods, even with a lower percentage of CO, death may occur, but other complications will arise that will affect their health for life, even if they don't die immediately. This is because they may experience periods of fresh air alternating with exposure to CO-contaminated air.

The maximum CO content that natural gas can reach is approximately 15%, a situation that would require either a 25% air deficiency (to reach the minimum air quantity) or a very poor air-gas mixture.

However, having 1% to 2% CO in flue gases is not unrealistic. Therefore, natural gas burners should be monitored periodically with instruments to check for the undesirable presence of CO and correct the situation, since visual inspection is not possible because there are no visible smokes or the flame color is not precise).

This means that, primarily for this reason and for economic reasons (energy loss), **the maximum acceptable CO level in natural gas combustion chimneys is generally 400 ppm** (parts per million, equivalent to approximately 0.04% CO) in the flue gases.

However, in a "good" and "properly adjusted" burner, the CO level should be practically "nonexistent."

Parts per Million (ppm): CO (carbon monoxide, toxic) in the atmosphere.

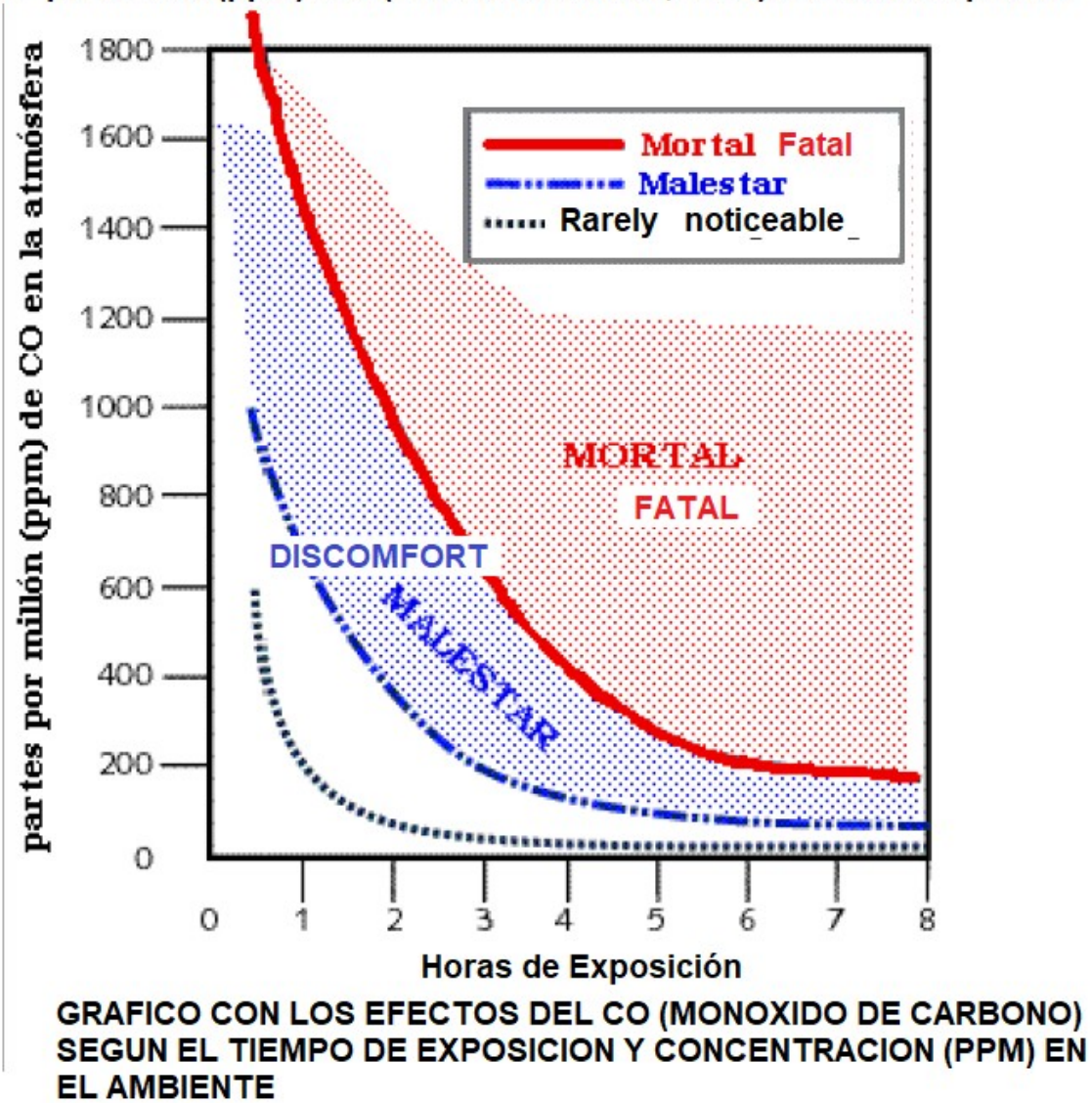


GRAFICO CON LOS EFECTOS DEL CO (MONOXIDO DE CARBONO) SEGUN EL TIEMPO DE EXPOSICION Y CONCENTRACION (PPM) EN EL AMBIENTE

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The composition of the chimney flue gases, assuming no CO (carbon monoxide) and the minimum amount of air used (without excess, which is theoretical; in practice, an excess of air will always be used, though it should be kept to a minimum), will be approximately the following percentages by volume:

Composition of chimney gases (Natural Gas)

Component	**on a wet basis**	**on a dry basis**
CO2.....	9.90%	12.20%
H2O.....	18.5%	0.00%
N2.....	71.6%	87.80%

See here the importance of the water (H2O) formed, due to the large amount of hydrogen (H2) in the natural gas.

At the time of "start-up" with the cold boiler a large amount of water is produced by condensation, which condenses in the boiler's furnace, which then evaporates, **but which is the cause of possible corrosion if this operation occurs day after day**).

In the event of a gas leak (detected by smell): do not turn on any electrical appliances, move people away from the area, and call the gas company (or fire department) as they have the appropriate equipment and knowledge (as well as training).

See the end of this section for some considerations regarding the supply of natural gas to burners.

Never attempt to detect a gas leak with a lighter, candle, or match. If it is necessary to check for a leak at the burner (i.e., the user's area), use soapy water (look for bubbles)!

We will see next point 4- The burner must be adjusted using instruments.